MISSION ENGINEERING

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ABSTRACT

Goddard Space Flight Center's projects are facing new challenges with respect to the cost effective development and operation of space-flight missions. Challenges, such as cost limits, compression of schedules, rapidly changing technology, and increasing mission complexity are making the mission development process more dynamic. This paper proposes a concept of "Mission Engineering" as a means of addressing these challenges. It is an end-to-end, multi-mission development methodology that seeks to integrate the development processes between the space, ground, science, and operations segments of a mission. It thereby promotes more mission-oriented system solutions, within and across missions.

Key Words: Aerospace, Unmanned Scientific Satellites, Mission Development

1. MISSION TRENDS

As technology rapidly changes in both onboard and ground systems, and as science moves towards more dynamic process studies, our missions, their operations, and the support systems are constantly evolving. Understanding these trends and managing change throughout the end-to-end system in a controlled and collaborative manner is essential to cost effective obtainment of mission objectives. This creates a challenging environment for GSFC projects.

Five mission trends that are contributing to GSFC project challenges are the increase in real-time science operations (moving from survey to dynamic process studies), fundamental changes in ground/space asset relationships, the movement towards distributed processing environments, the demanding GSFC mission model, and trends towards small spacecraft series.

First, the present mission model shows a trend from survey-type missions to missions and sets of missions that involve more precise, dynamic study processes. This is resulting in higher

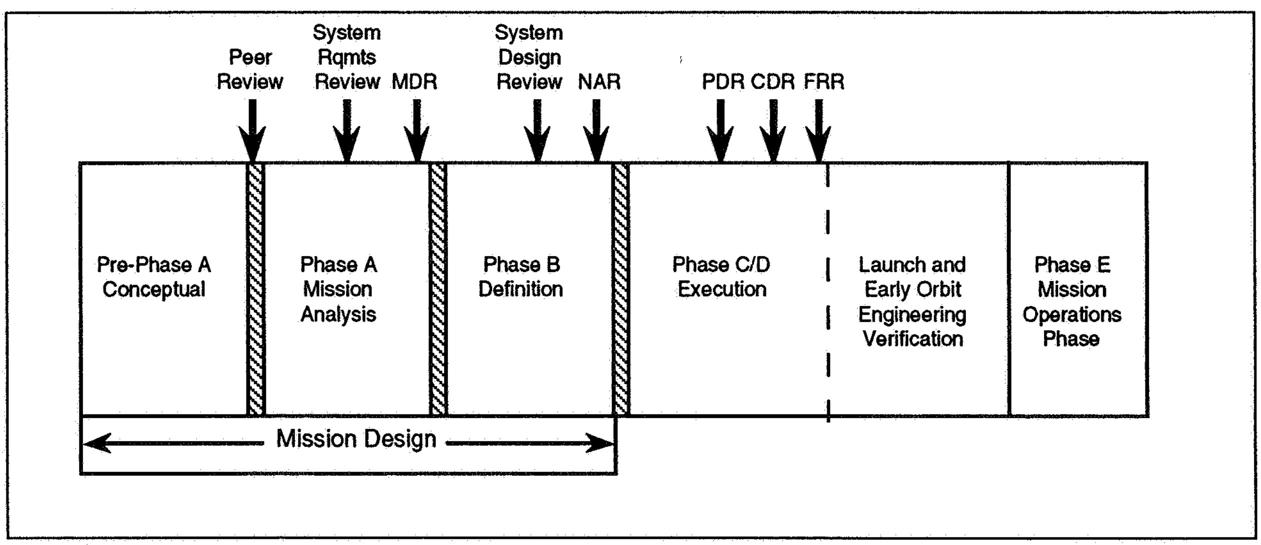

Figure 1: GSFC's Mission Life Cycle

burst data rates, less advanced planning, more targets of opportunity, correlative science operations, and coordinated campaigns between spacecraft missions. This creates increased demands upon the space, ground, and operations segments of a mission and implies a closer coupling of spacecraft and science operations. Science operations are therefore becoming more of an integral part of the planning and realtime systems.

Secondly, the availability of more powerful flight processors is allowing the movement of more functions on-board and allowing more flexibility and autonomy in mission operations. This is evolving the relationship between the ground and space segments, moving away from a ground master, spacecraft slave relationship to a more peer-to-peer level of operations. This requires more coupled engineering of space and ground segments, and changes the nature of normal and fault condition operations.

A third trend is the growing distribution of ground and science systems that support a mission. Today's technology is emphasizing moving data rather than people using data driven processes. This trend requires more up-front operations and systems planning to ensure that the mission objectives can be met while handling the contingencies that occur in the course of a mission. This trend places more emphasis on the early definition of information exchange, interface design, and element interaction.

The result of these three trends is a tighter operational coupling of the space, ground, science, and operations elements during operations, and therefore requires segment coordination within an end-to-end mission system earlier in the mission development process. Failure to do so can result in costly modifications and redesign, and use of systems in ways not intended (causing system stress and error potential).

Finally, the GSFC mission model and the trend towards smaller spacecrafts in a collaborative series (versus the previous single, large spacecraft approach) has resulted in many simultaneous mission processes and common operations and facilities for spacecraft series. It is now necessary to create a conscious, structured process for working across missions to promote reuse and sharing, thereby achieving additional economies.

In an effort to met these and other challenges the concept of a Mission Engineering process is provided. This concept provides the necessary interactions between the elements to ensure that mission trades are conducted (building the best "mission" solution), exchanges of information are understood, planned, and performed, and the systems are designed for their intended use.

2. WHAT IS MISSION ENGINEERING?

Mission Engineering is fundamentally a process improvement concept that addresses the interactions between the main mission elements

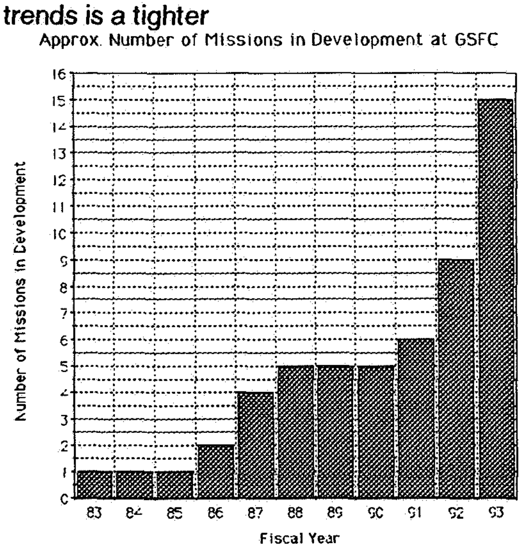

Figure 2: GSFC Mission Development Model

of space, ground, operations, and science. It is a structured, conscious effort at integrating the traditional space and ground segment development activities, applying the operations engineering principles, and embracing the inclusion of the now realtime science element in a development and operations process over the complete mission life-cycle. It also provides a structured communication mechanism for addressing mission trades early in the mission development process (particularly during the critical Phase A and Phase B study efforts where fundamental strategies and budgets are established), a means for developing and applying new technology and standards in a controlled manner, and a means for applying past lessons learned for continuous improvement. Its emphasis is on understanding the overall operational and science vision and in sharing that vision across the main mission elements.

Given the cost constraints of today's environment, the Mission Engineering process seeks to make the best use of standards, policy, and lessons learned from previous missions in order to identify the key mission drivers and to address them in a timely manner. It focuses upon applying the best skills and experience to the right problems in order to quickly resolve operational issues, address life-cycle costs, and to ensure that the correct system is built the first time. The key is to understand and discuss the essence of the problem and not create a bureaucratic process that hides key issues.

A key objective of this concept is to enhance interelement communications and to ensure that operational impacts of system design decisions are understood. Communications is a key element because the process emphasizes the need for concurrent mission definition activities in order to compress the development schedule for smaller missions. This works to anticipate the mission needs with respect to reusability of ground and science components and proven concepts. The key is not to recreate infrastructure, but to focus project resources on the science that is to be obtained.

2.1 Dimensions of Mission Engineering

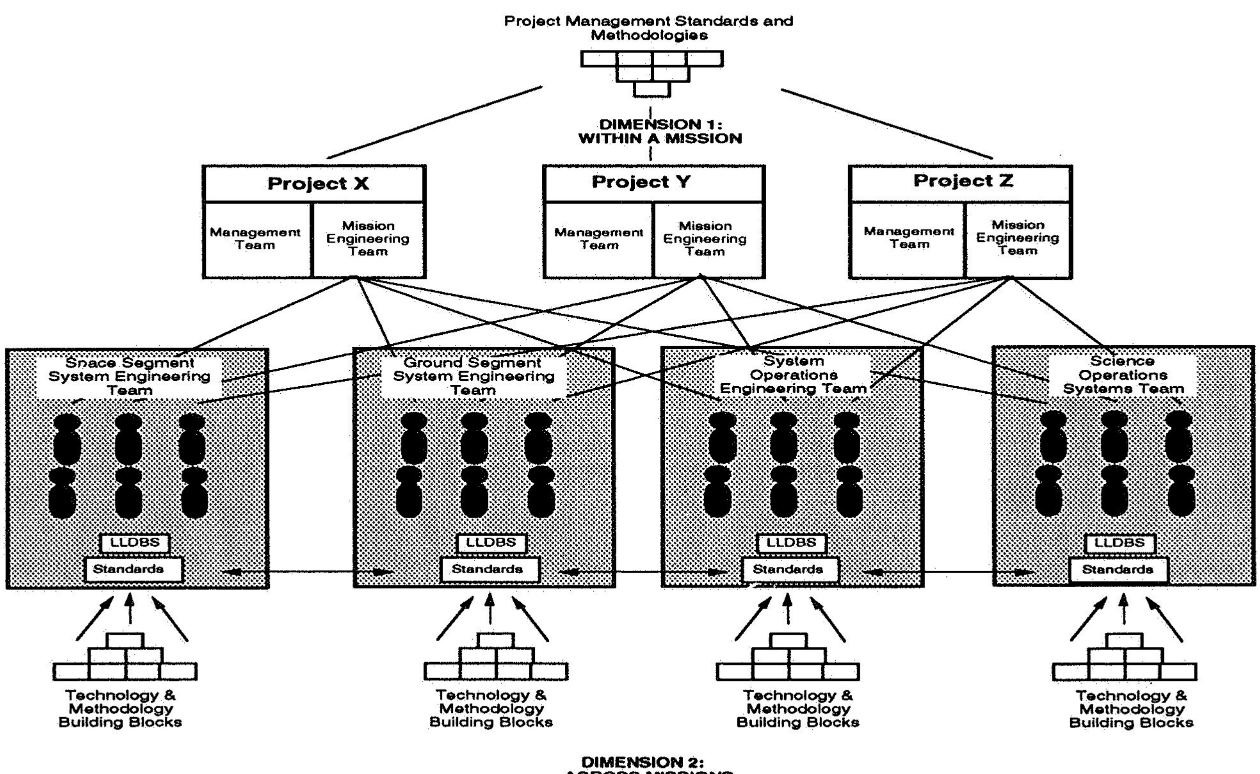

Figure 3: The Mission Engineering Architecture

The Mission Engineering concept has two dimensions: 1) within a mission and 2) across missions. These two dimensions are active simultaneously and interact with each other.

2.2 Within A Mission

Within a mission, the Mission Engineering process emphasizes addressing mission and science operations in a structured manner early in the development process. It requires a *mission engineering team (space segment, operations, and ground system engineer plus science representation)*. The objective is to trade ground, operations, and science alternatives in a concurrent manner with spacecraft design efforts with the emphasis placed on mission management team defined and weighted decision criteria.

The process at this point is driven by a process guideline to ensure completeness in order to address all mission aspects. It seeks to develop and maintain a complete operations concept or vision of the mission and to communicate this to all elements. In many of today's missions this vision is baselined once and left in Phase A. The Mission Engineering process is based upon the concept of applying operational experience and science expertise early in the mission development phase in order to draw from lessons learned on previous missions. It also provides a means for injecting through these individuals existing capabilities in the ground and science infrastructures.

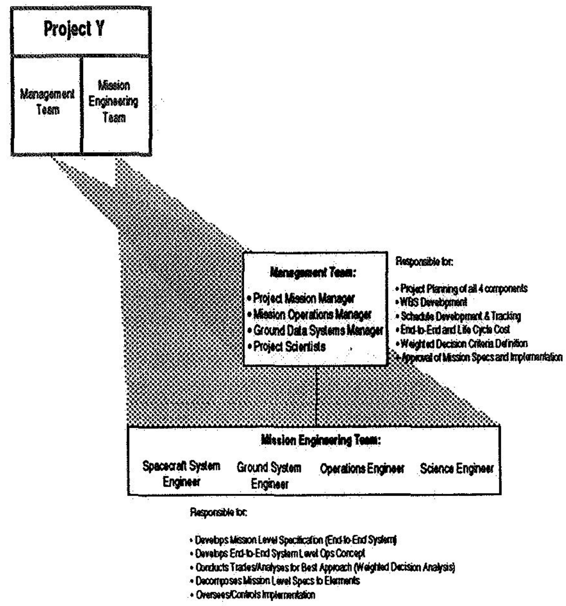

Figure 4: Dimension 1 Organization

History has proven that it is more cost effective to address these issues and resolve them early in a mission rather than later. Unfortunately, in

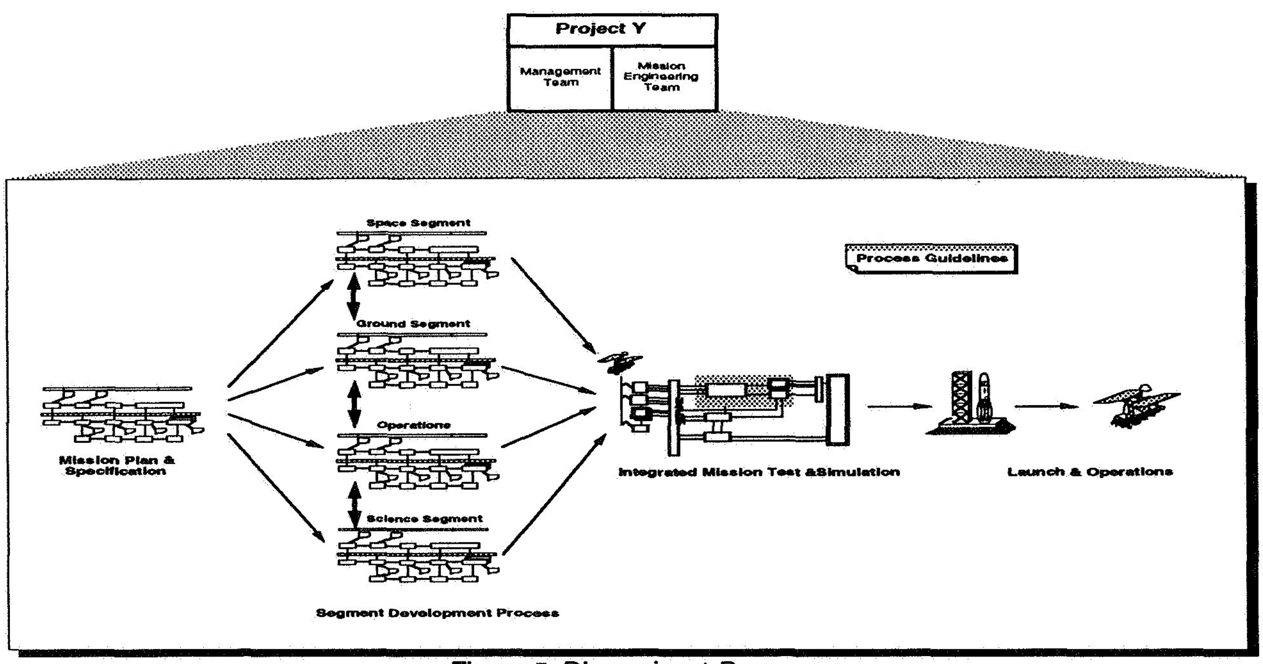

Figure 5: Dimension 1 Process

many missions they are addressed late and cause increased costs and operational readiness delays. Mission Engineering encourages that the right questions be asked up-front and that contingency scenarios be addressed. Without applying the proper skills and experience the same mistakes are made from mission to mission. These problems are subtle enough so that they are only discovered during the end-to-end testing phase rather than at reviews.

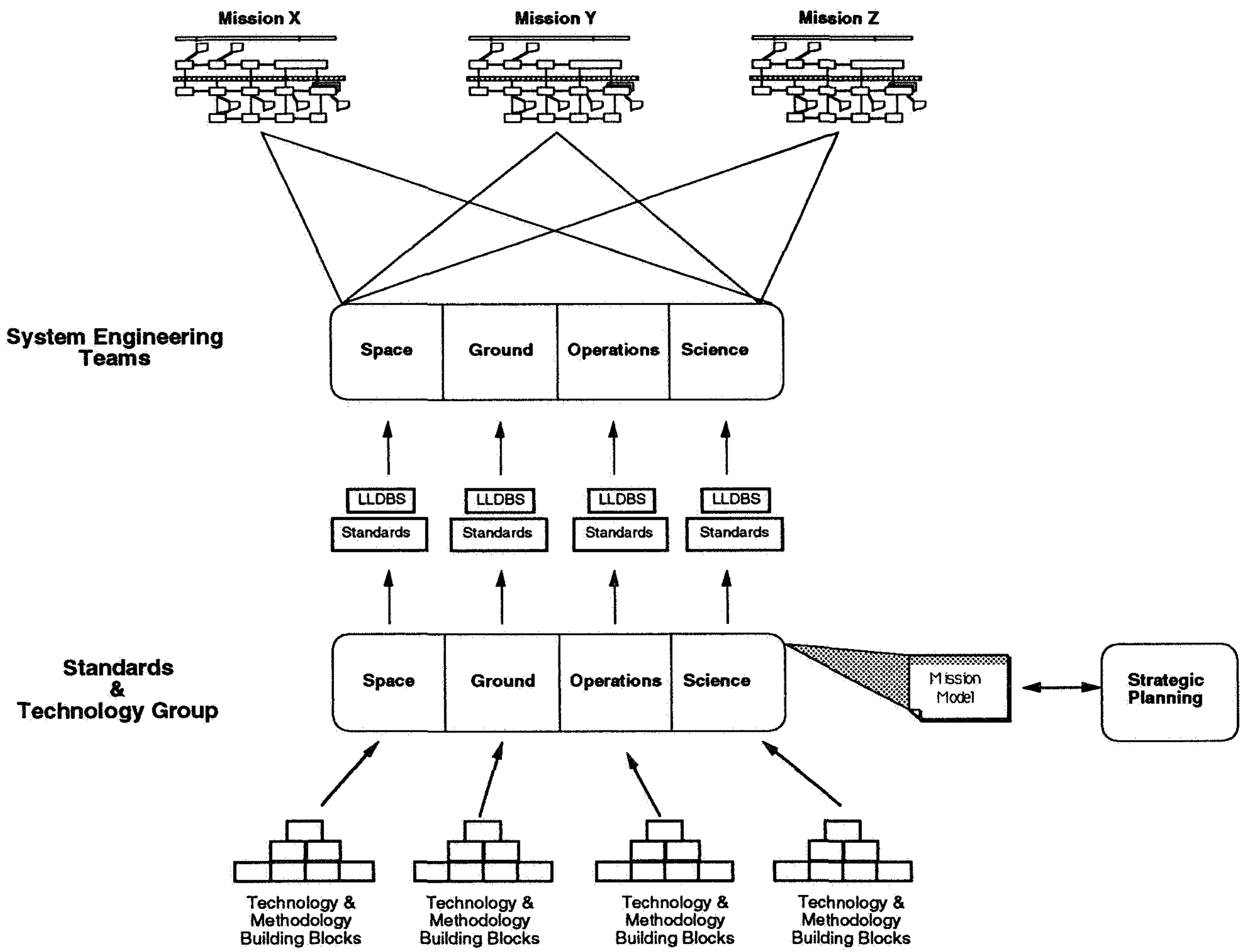

Figure 6: Dimension 2 Organization and Process

2.3 Across Missions

GSFC has been successfully implementing individual missions for over 30 years. Within the past ten years the mission load has been relatively low, with major free-flyer launches at a rate of one or two per year. During the period from 1986 (Challenger disaster) to 1989 no major launches occurred. Therefore we have been lulled into a process which did not promote across mission engineering, nor necessarily need it. However, today the mission load is quite different, with many major missions scheduled for launch from 1994 to 1998 and beyond. We must now find ways to improve our processes for looking across missions which are in parallel development stages and search for additional economies and common solutions. The Mission Engineering process therefore provides a means for integrating development and operations across missions, complimenting the individual "within a mission" dimension. The intent is to promote the sharing of technology, applications, and operations across missions so that each separate project does not reinvent the wheel nor implement a different solution for a like function. Other less challenging but economical benefits such as mass buys can also be obtained.

The products of this element (maintained by a multi-segment standards and technology group) are mandated standards, reusable ground and science software, multi-mission technology, and requirements for the support infrastructure. Also provided is a central repository for lessons learned, a forum for operational issue resolution, and the development of operational personnel. An overall mission model is maintained and is used to articulate noted trends back to the various groups, as well as to strategic planning elements. Multi-mission engineering is then imparted to active mission development processes by multi-segment systems engineering organizations using common standards and technology. It is executed by a senior system engineering team representing the space, ground, science, and operations elements.

2.4 Why Mission Engineering?

The lack of a conscious, structured multi-mission process for projects leads to a significant increase in the overall mission budget. Lessons learned and technology gained on one mission will not be systematically shared with other missions if there is no mechanism for sharing such information. Solutions to common problems will be applied differently, limiting reuse and the economies that come with it. Individual missions will provide a suboptimization of agency resources. There needs to be a proactive advocate that can encourage projects to reuse systems and operations across missions. Due to the rising MO&DA budget and the agency attention at reducing operations costs, a focus needs to be provided that understands the implications of operational concepts, spacecraft design, and infrastructure changes. Without such a focus the operations budgets will continue to grow and in times of constrained budgets new and exciting science missions will be prevented from taking place. Mission Engineering provides a forum for preventing future operations increases.

Presently, there is no element responsible for understanding the strategic implications of mission model changes. A good example is the overwhelming trend in flight projects toward small, ground station-only spacecrafts, yet the operations support capabilities continue to focus critical mass on the TDRSS system with no major plans for ground station enhancements. A similar divergence exists in the trend towards higher data rates and more realtime data requirements (in support of dynamic process science studies), yet no major changes in the data transport capabilities seem imminent. The systems and commercial enterprises that comprise NASA's communication and data acquisition infrastructure take years to change. The analysis of the mission model and science needs has no focus to presently map future needs into these systems. Technology is changing faster than the infrastructure can be cost effectively changed. The Mission Engineering forum provides a mechanism for attempting to anticipate these types of changes.

This process and its corresponding personnel provides a means of improved communications between organizational elements at GSFC and provides project managers a forum to have operational system's issues analyzed. It will improve communications which in turn will improve the timeliness and quality of the products provided. It also has side benefits of promoting team development and increasing the overall knowledge of each member of the team to the sensitivities, cost drivers, and needs of the other. It will enhance a "one team" spirit among the center's directorates. Finally, given a documented structured process for mission engineering, and the ability to capture and apply lessons learned, the concepts of continuous improvement can now be better applied.

3. SUMMARY

Mission Engineering is a process improvement concept that is beginning to be implemented at GSFC. A working group will soon be formed to develop the joint process. Steps are presently underway to address the skills needed to assemble an effective dimension 1 (within a mission) team, and a joint interelement working group is being explored to formally address the multi-mission dimension. We feel this concept will address the many challenges facing us including the need for “more for less”.